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Point contact Josephson junctions

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*Document Version*

Publisher's PDF, also known as Version of record

*Publication date:*

1977

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Tolner, H. (1977). Point contact Josephson junctions. s.n.

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## SUMMARY

A description is given of relatively high impedance ( $10 - 1000 \Omega$ ) superconducting niobium point contact Josephson junctions, which can be used as wide-band detectors of millimeter and submillimeter radiation. The antenna characteristics of the employed structure are discussed and have typical impedance values of the order of  $100 \Omega$ . Using a burn-in method the junction resistance can be approximately matched, so that these junctions couple optimally to external radiation. As a result of an electropolishing treatment and the burn-in process, these junctions are mechanically and electrically stable at 4.2 K.

The quality of the junctions, that can be expressed by the product of the maximum possible supercurrent  $I_c$  and the normal state resistance  $R$ , has been gradually improved. At this moment  $I_c R \sim 1300 \mu V$  which is about  $2/3$  of the theoretical maximum value. A review of the theory on wide-band detection shows that fortunately resistance values of about  $100 \Omega$  are also optimum to achieve a maximum responsivity to external radiation and a minimum 'noise equivalent power' (NEP).

Using a Michelson interferometer the spectral response has been determined for several resistance values as a function of the frequency of external radiation ( $\sim 300$  GHz). The resistance has been decreased more or less continuously by controlling the burn-in process. A strongly peaked response is found with a bandwidth of about 40 GHz, in quantitative agreement with earlier estimates based on the antenna theory.

The frequency of maximum response  $\nu_r$ , however, cannot be related to antenna resonance frequencies. On the other hand, the change of  $\nu_r$  with the junction resistance  $R$  can be explained by the Josephson effect itself. In underdamped junctions the supercurrent state is unstable with regard to phase oscillations, induced by external radiation, at a frequency equal to the plasma frequency (plasma oscillation of Cooper pairs). It is shown that this frequency  $\nu \propto R^{-1/3}$ . This corresponds with the experimentally found relation between  $\nu_r$  and  $R$ , if  $R$  is so high that the junction is underdamped. The response peaks for  $R \approx 100 \Omega$  at  $\nu_r \approx 150$  GHz. Used as a wide band detector, the minimum detectable temperature difference of the detector is estimated to be  $\Delta T \approx 5 \times 10^{-3}$  K corresponding to a NEP  $\approx 3 \times 10^{-15}$  W/Hz $^{1/2}$ , at  $\nu \approx 150$  GHz.